Low Temperature Interconnection of PVD Aluminium Metallization

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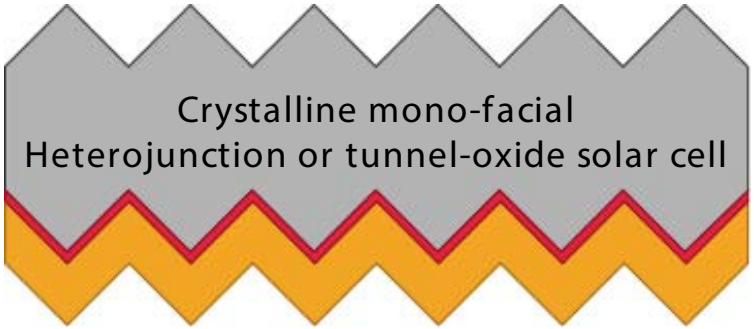
Starting point

- Crystalline, mono-facial heterojunction or tunnel-oxide based 6‘‘ solar cell in development [1]
- Full-area rear metallization with 150 nm sputtered ZnO:Al and 2 µm thermally evaporated Aluminium [2]
- Due to heterojunction layers, temperature must not exceed 200 °C

Concept



Full-area metallized rear with thermally evaporated Aluminium

[1] Glunz S., et al, 31st EUPVSEC, 2015
[2] Nekarda J. et al. , 34th IEEE PVSC, 2009, pp. 892–896

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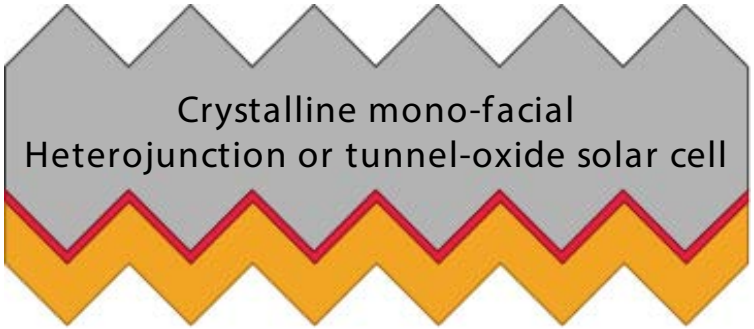

Full-area metallized rear with thermally evaporated Aluminium

- Task: Find appropriate low temperature interconnection technology
- Challenges: **Aluminium** and **low temperature**

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How to interconnect (PVD-)aluminium?

Al is difficult to interconnect due to its native oxide

Approaches

[3] Schmitt, et al. Energy Procedia 2013;38:380–6.
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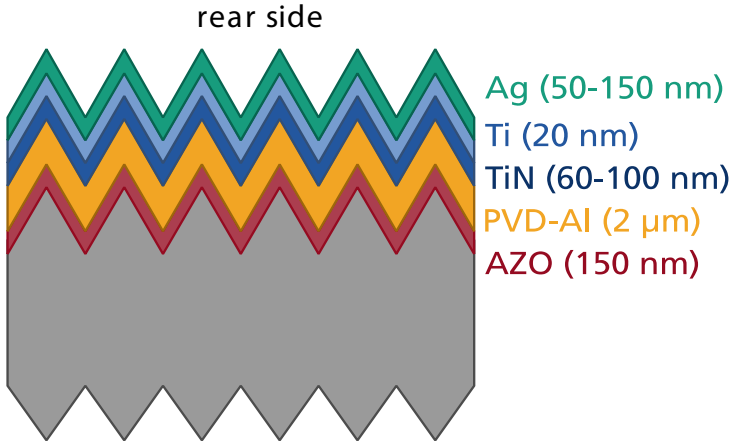
- Solderable stacks
  - Jung and Köntges: Al/Ni:V/Ag [6]
  - Kumm: Al/TiN/Ti/Ag [7]
    - Designed for annealing-stability at > 300 °C
    - Tested with SnPbAg solders



Schematic of solderable stack on wafer developed by Kumm et al. [7]

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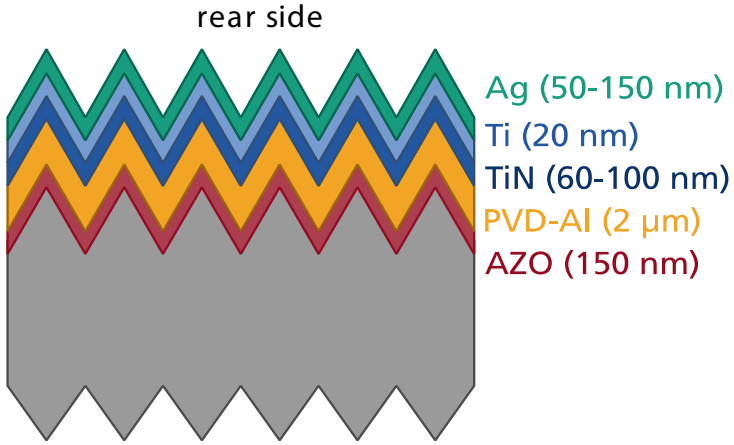

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- New approach: TiN is omitted as process temp. remains at max. 200 °C
- Demonstrate interconnection with low temperature methods

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Evaluation of low temperature interconnection methods

Isotropic electrically conductive adhesives (ECA)

Sn43Bi57 and Sn41Bi57Ag2-soldering

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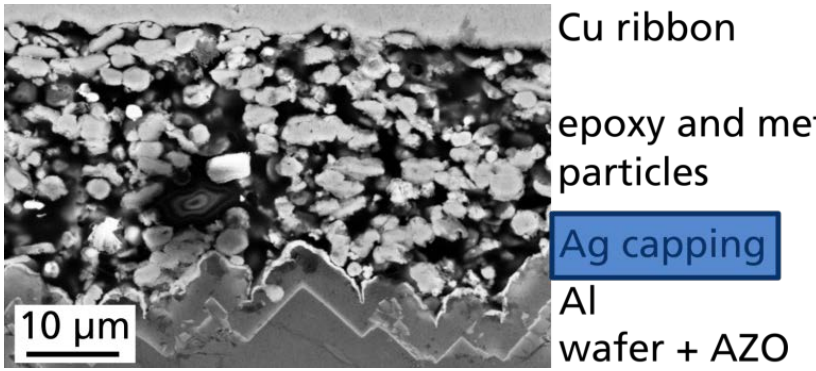
Isotropic electrically conductive adhesives (ECA)



Simplified stack: Al/Ag (Does it work?)

Two silver-reduced glues are tested

Sn43Bi57 and Sn41Bi57Ag2-soldering

Evaluation of low temperature interconnection methods

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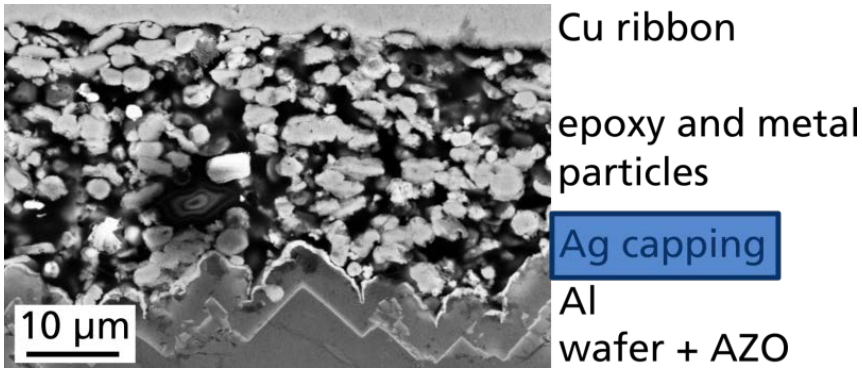

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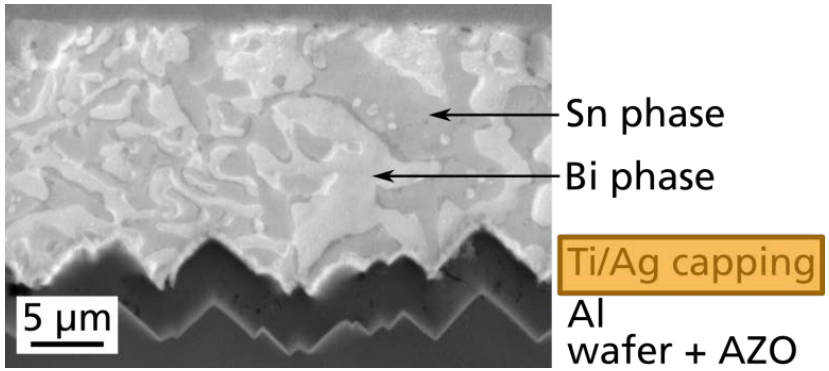

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Initial solder tests show, Ti is still necessary as adhesion promoter

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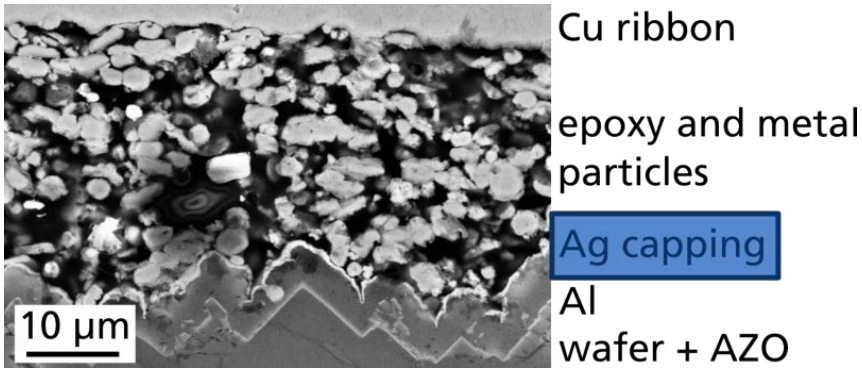

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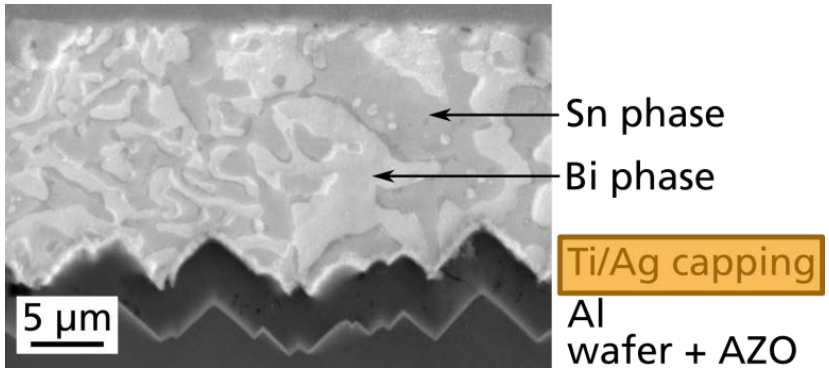

Simplified stack: Al/Ti/Ag

Initial solder tests show, Ti is still necessary as adhesion promoter

Assessment program

- Peel tests
- Contact resistance
- Accelerated aging

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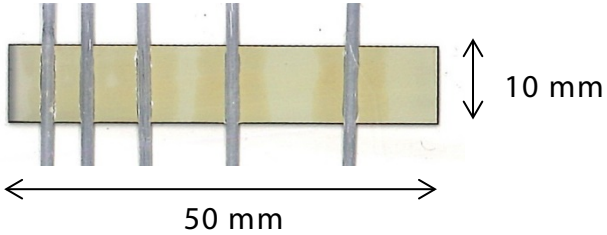
Samples and characterization

- All tests made at **textured, metallized wafer-level** (no p/n-junction)
- Semi-automatic soldering / curing of ECA
- Peel-tests according to DIN 50461
  - 90° angle, 50 mm/min speed
- Contact resistivity with TLM-structures [8]
- TLM-structures are laminated in glass-EVA-backsheet
- Encapsulated TLM-samples are exposed to thermal cycling and damp heat tests

ECA interconnected wafers during peel test



TLM sample with soldered ribbons perpendicular to piece of metallized wafer

[8] Chern, Oldham, IEEE Electron Device Letters 5(5), pp. 178–180, 1984

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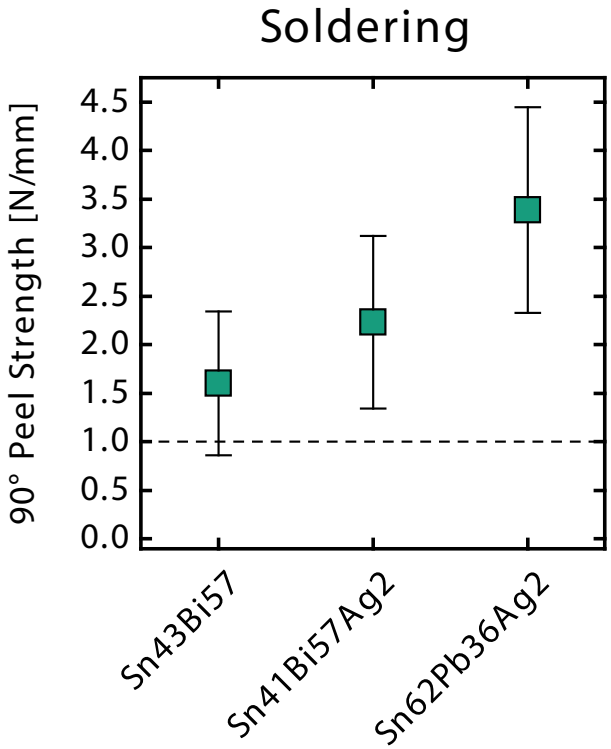
Peel tests



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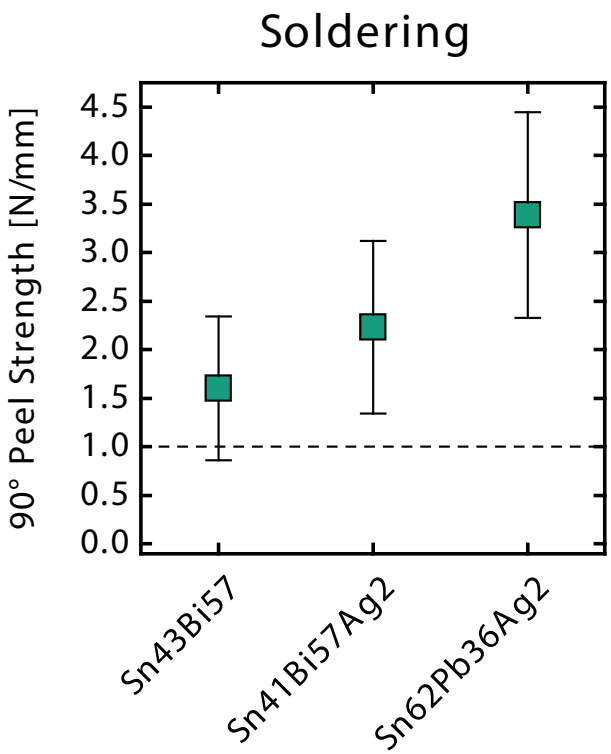

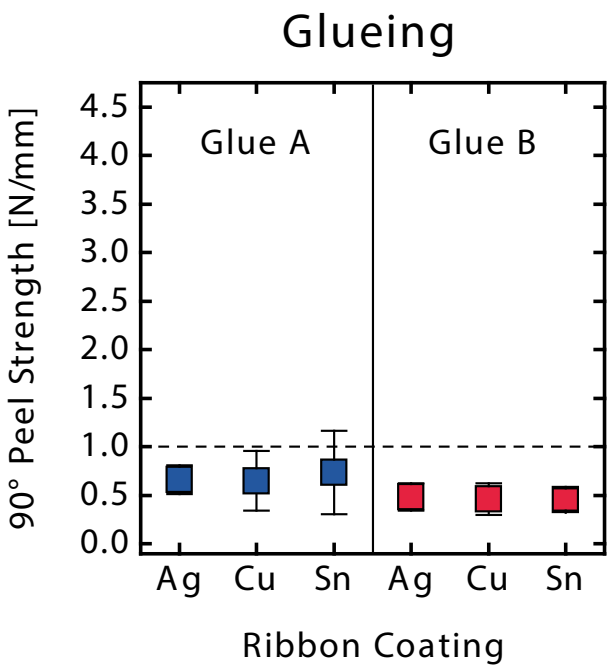

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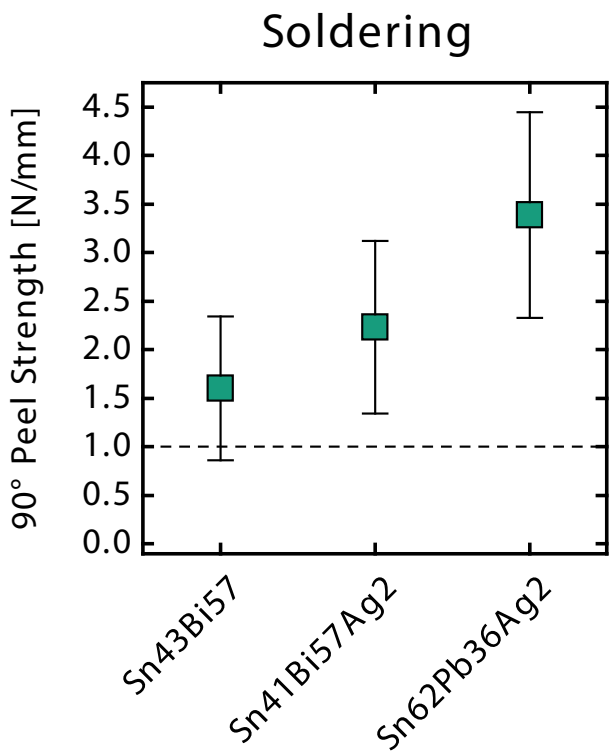

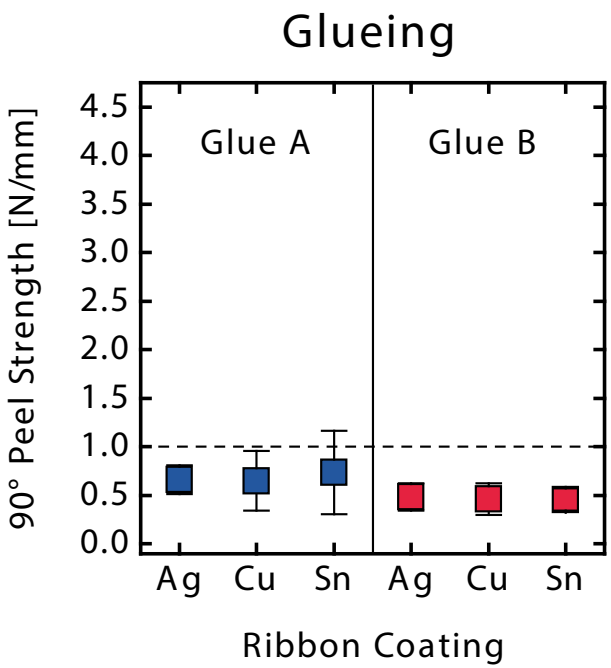

- Low temperature soldering: 1.5 – 2 N/mm
- Conductive glueing: 0.5 – 1 N/mm
- Similar peel strength of ECA joints with various ribbon coatings

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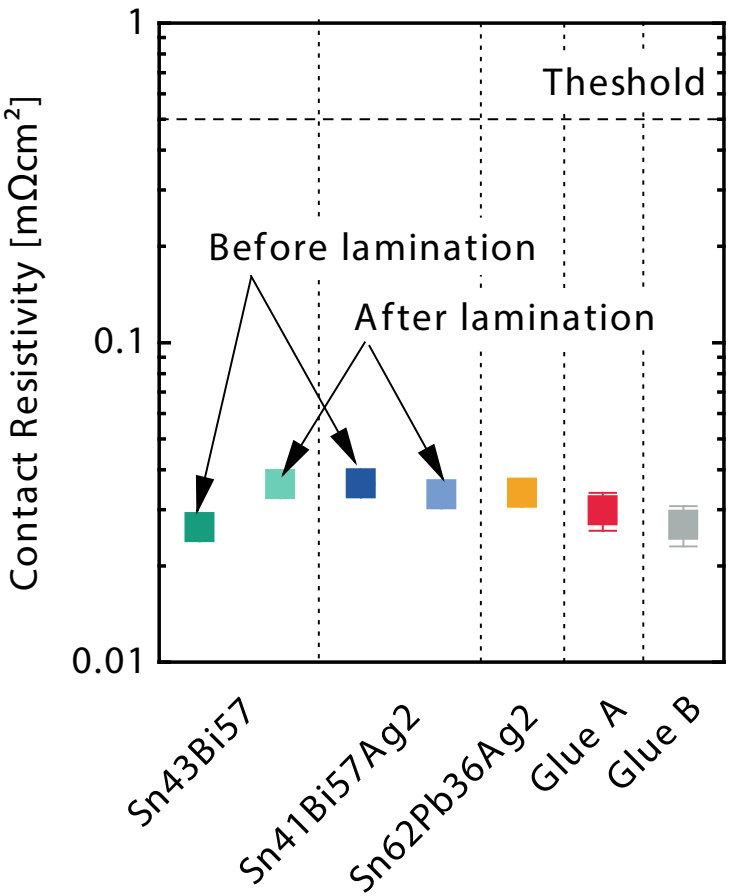
Contact resistivity

Contact resistivity

- No reduction of FF to be expected if contact resistance remains below 0.5 mΩcm² (3BB, large solder pads) [9]
- Contact resistance of soldered samples is tested before and after lamination (~ 160 °C)
  - Remelting of solder occurs
- Slight increase of contact resistance for Sn43Bi57 after lamination observed
- Glueing achieves same contact resistance as soldering



[9] Zemen Y, et al. Solar Energy Materials and Solar Cells 2013;109:155–9.

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Reliability
Thermal aging of soldered interconnections

- Thermal aging is an important reliability test for solder joints [10]
- Metallographic cross sections are isothermally aged in N_2-atmosphere at 100 °C and 115 °C for 15 h to 155 h
- 100 °C – group is peel tested after aging

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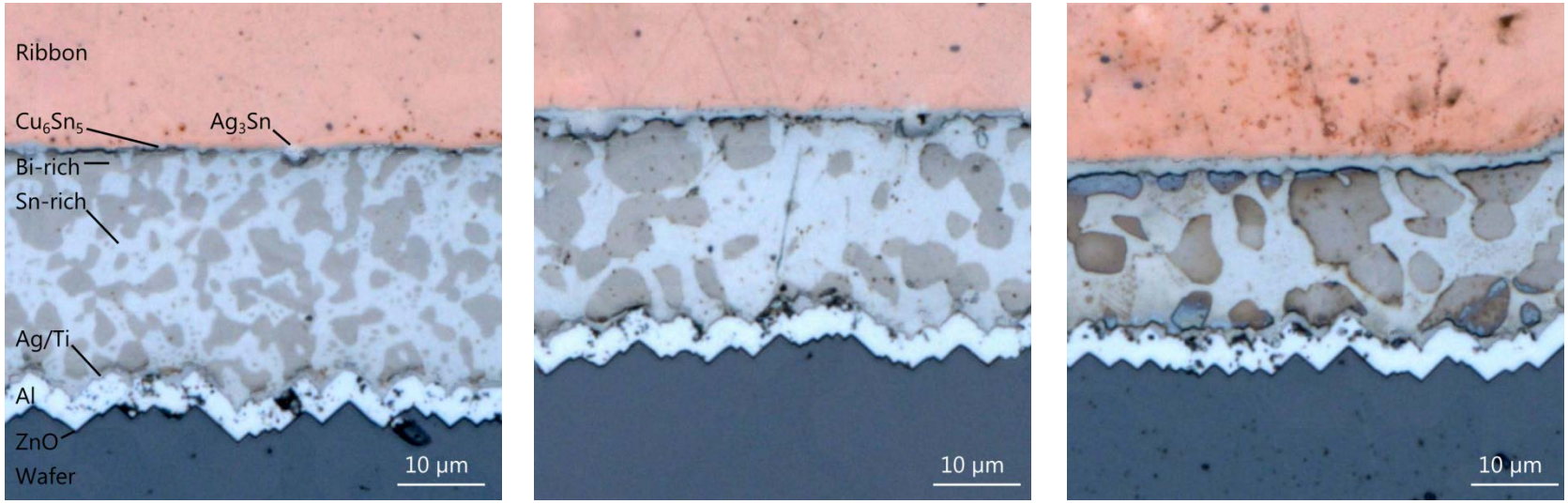
SnBiAg as soldered | **aged for 85h at 115 °C** | **aged for 155h at 115 °C**



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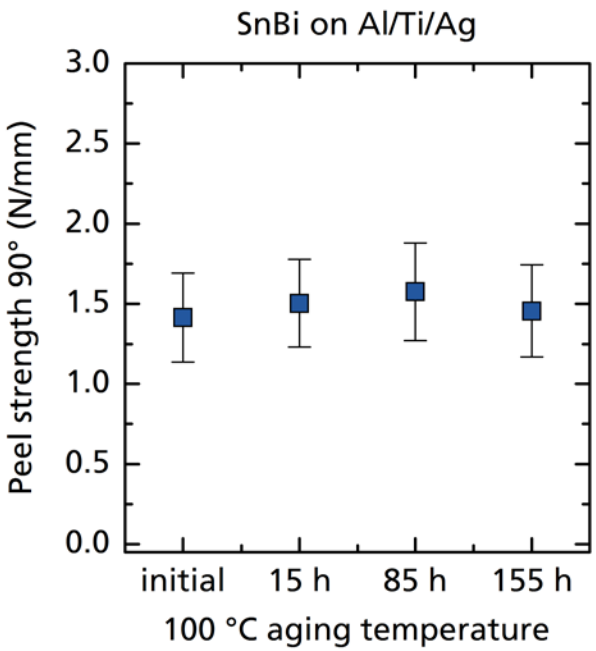

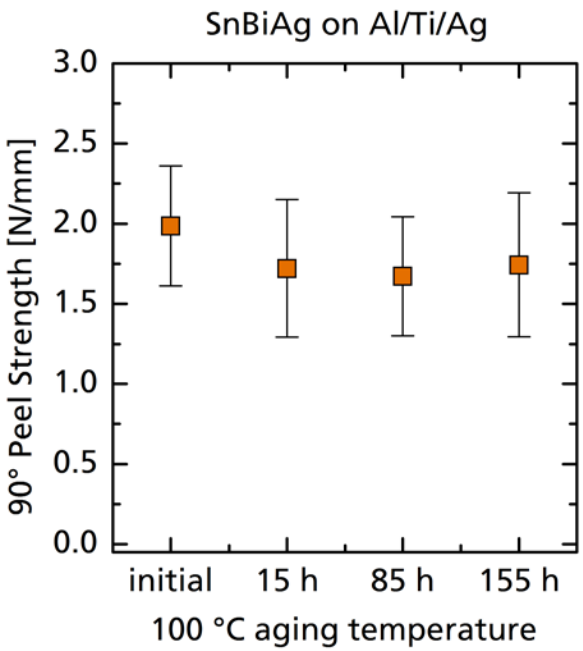

- Short term thermal aging at 100 °C does not lead to a reduction of peel strength yet

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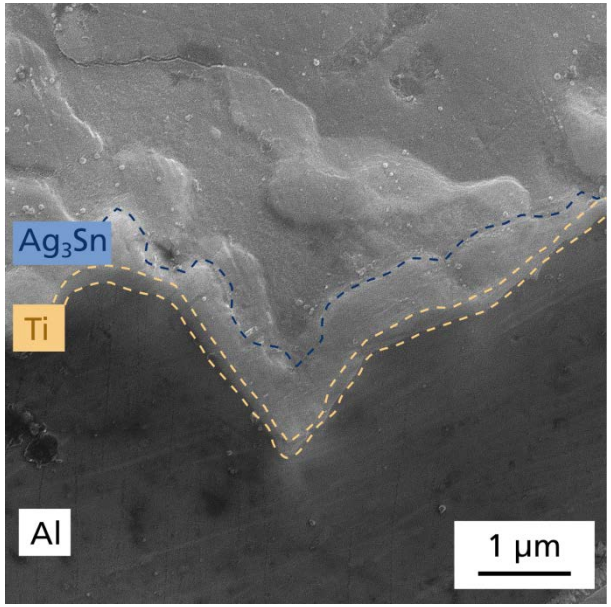
Reliability
Thermal aging of soldered interconnections

SnBiAg solder bond initially



[11] Vianco PT, et al. Metall and Mat Trans A 2006;37:1551–61.
[12] Kim HK, et al. Appl. Phys. Lett. 1996;68:2204.

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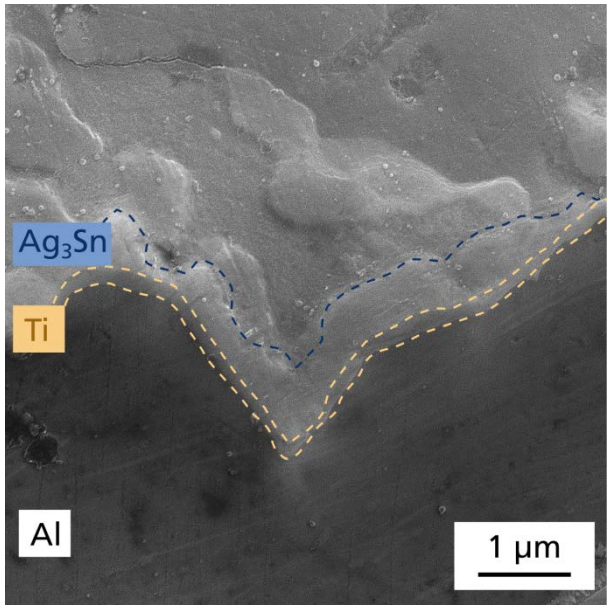
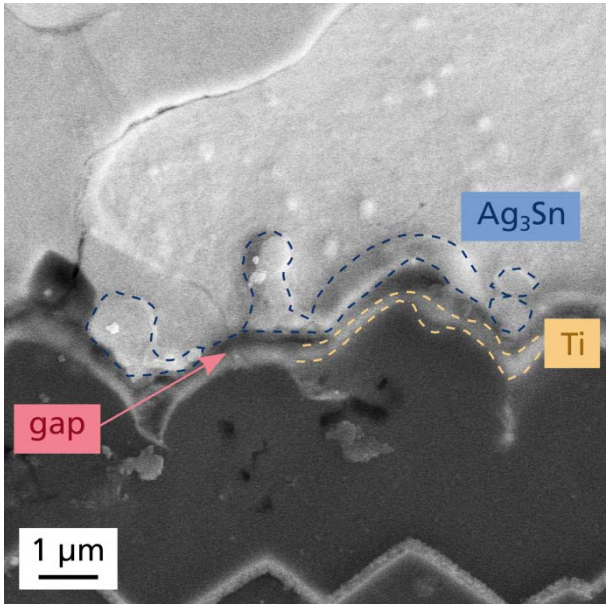
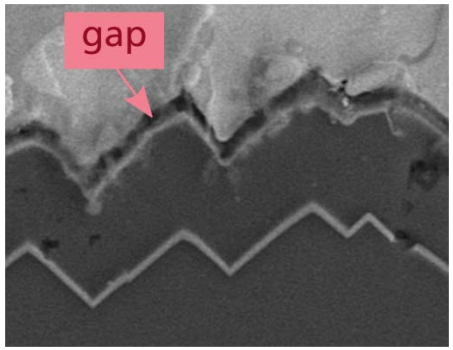


After thermal aging at 115 °C for 155 h





- Thin layer of Ag is (at least partly) dissoluted in the solder and transformed into Ag_3Sn during initial soldering [11]
- Further thermal aging leads to „spalling“ of Ag_3Sn spheriods [12]
- May effect bond strength in later stages of aging

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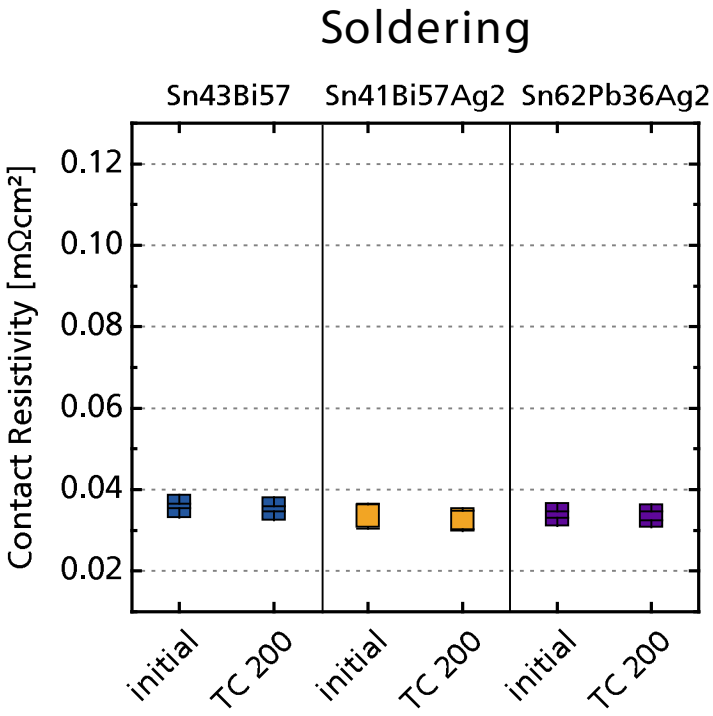

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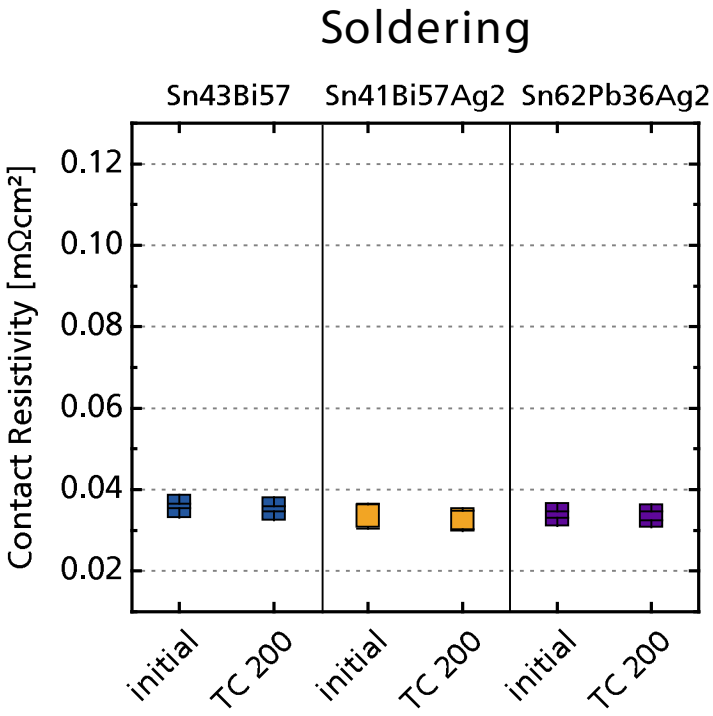

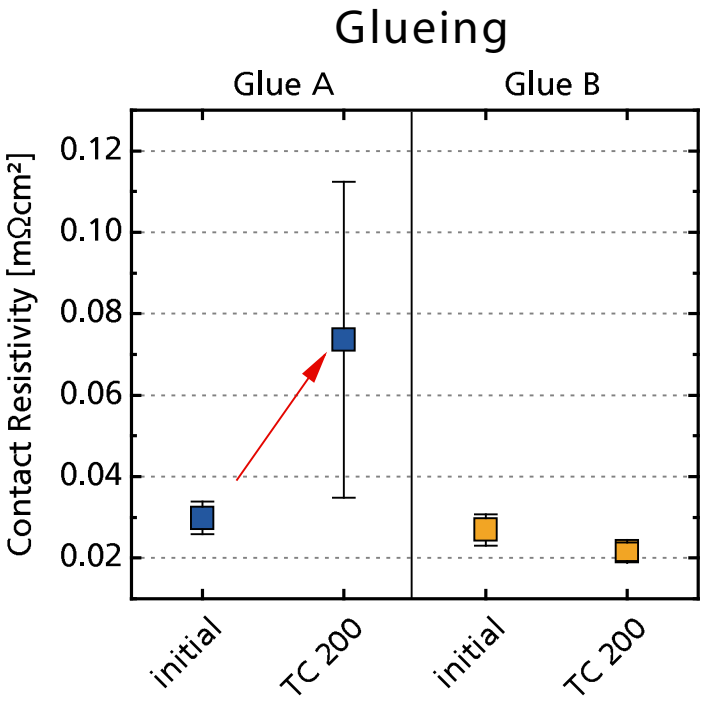

- Contact resistance of soldered joints on Al/Ti/Ag is stable after TC 200
- Increase of contact resistance for one glue, but still below 0.5 mΩ cm²

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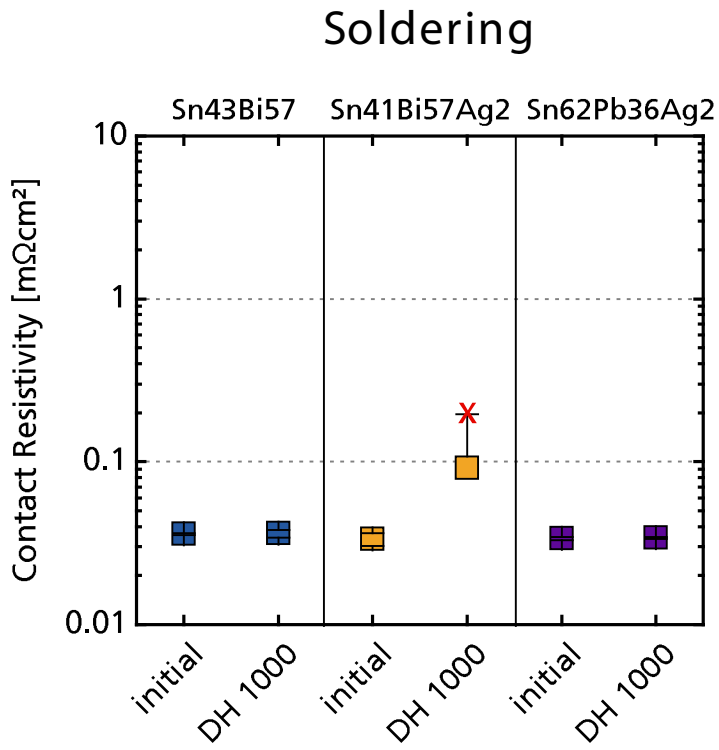
Reliability
Damp Heat



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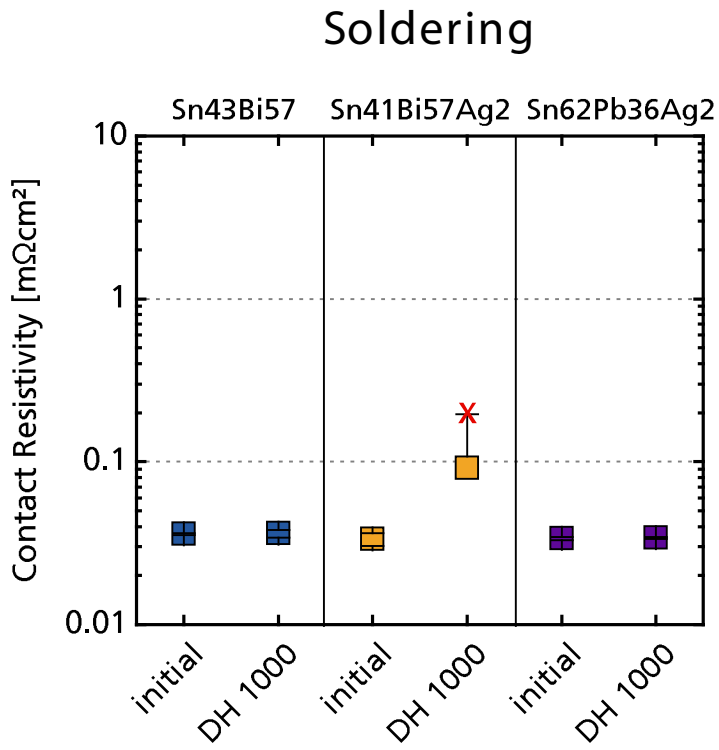

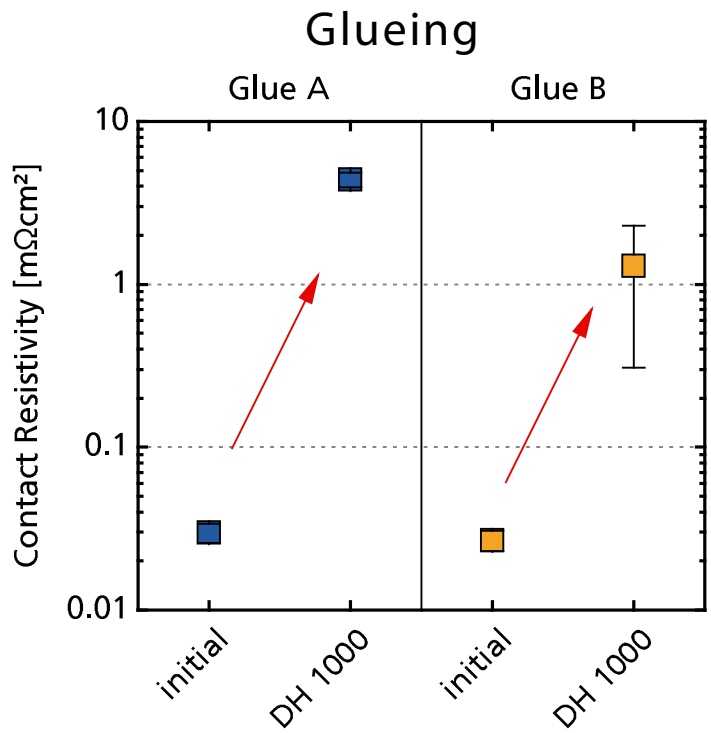

- Contact resistance stable after DH 1000 with soldered interconnects on Al/Ti/Ag except in one case
- Contact resistance of glueing on Al/Ag increases strongly

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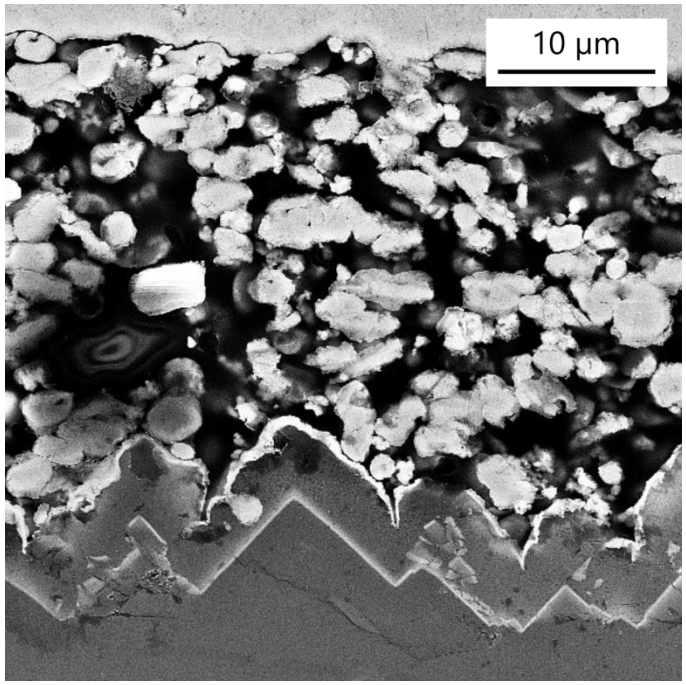
Observations after damp heat

Adhesive joint before aging



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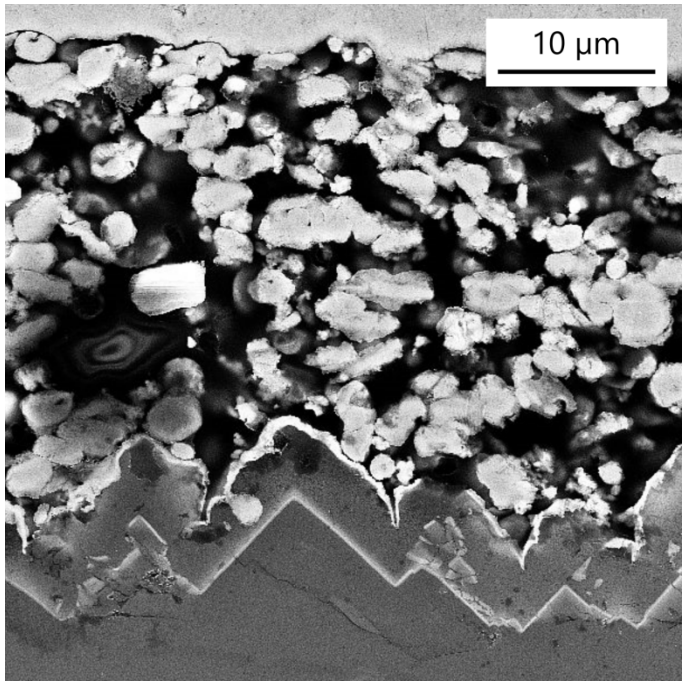

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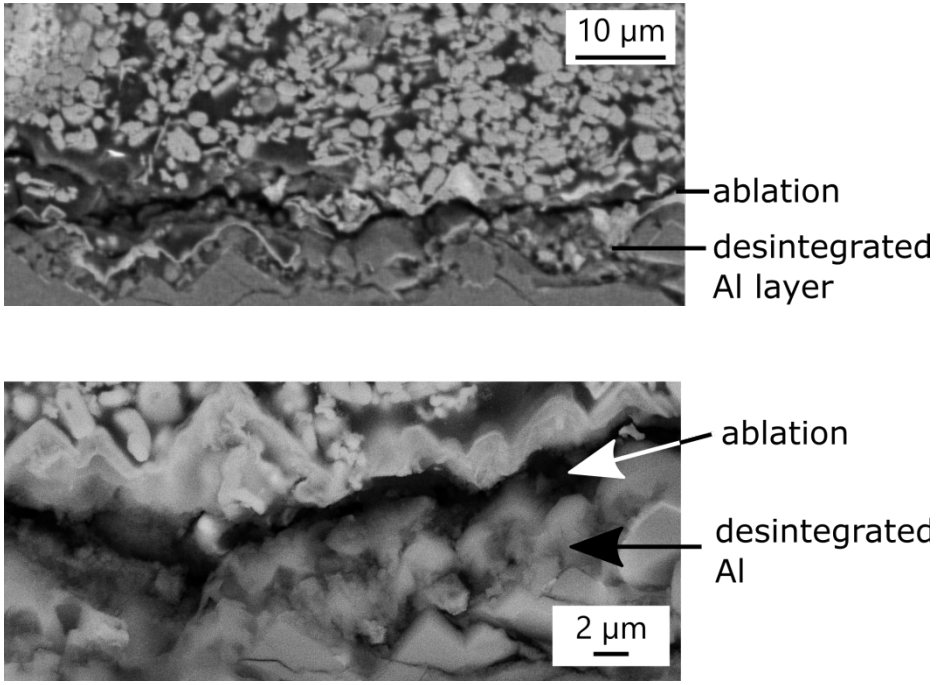

- Partial ablation of Ag capping
- Decomposition of Al layer
- Accumulation of oxygen in the Al layer (determined via EDX)
- Simplified stack Al/Ag is not reliable to interconnect

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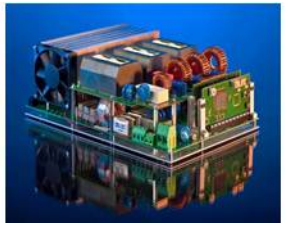
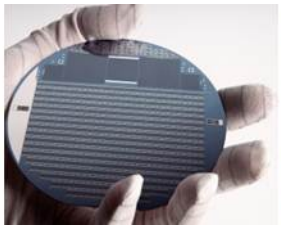
Conclusions

- Demonstration of interconnections on a simplified solderable Ti/Ag stack on PVD-aluminium
  - Peel forces with SnBi and SnBiAg above 1 N/mm and good electrical contact
  - No degradation of resistance after first environmental chamber tests
- Simple Ag-capping of Al:
  - No peel strength for soldering
  - Peel strength of glueing 0.5 – 1 N/mm good in the expected range
  - Contact resistance is as low as soldering
  - **But:** Increase of contact resistance in damp heat observed
  - Desintegration of layer and oxygen accumulation observed
  - Modification of stack is required

Thank you for your attention!

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Bundesministerium für Wirtschaft und Technologie

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